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Summary Analysis of the Material Condition of the KC–135 Aerial Refueling Fleet

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Overview

This is a report on what we have found in our analysis of the material condition of the Air Force KC–135 aerial refueling fleet. This work is still under internal CNA review. We are technically reviewing the statistical analyses and data, and documenting the findings presented in this paper.

Tasking

Section 345 of the 2004 National Defense Authorization Act (NDAA) calls for an independent assessment of the material condition of the Air Force's fleet of KC–135 Aerial Refuelers. This assessment must include the following for fiscal years 1996 through 2003:

1. Trend analysis for operational readiness
2. Trend analysis for the number of man-hours of organizational-level (O-level) and depot-level (D-level) maintenance required
3. The number of aircraft grounded due to corrosion and length of time each aircraft was grounded pending corrosion repair
4. An itemization of improved corrosion repair processes which resulted in a decrease in the number of manhours required for control and treatment of corrosion
5. An analysis of the relationship between trends in corrosion repair manhours and corrosion repair process improvements
6. An analysis of major structural repairs (MSRs) required due to corrosion.

Approach

We gathered and synthesized the necessary information in three ways:

— Review of existing documentation, which is extensive

— Interviews with knowledgeable individuals, including staff at the organic depot at Tinker AFB in Oklahoma City, Oklahoma

— Mathematical and statistical analysis of data provided to us by the Air Force.

For most of the quantitative analysis, at both the O-level and D-level, we used data in which the unit of observation was the individual aircraft. One limitation was that no usable depot data were available for years prior to 1998. Also, we evaluated depot maintenance at Tinker AFB only. Because of time constraints, we did not evaluate maintenance activities at the two commercial facilities that also do D-level work on KC–135s.

Overall assessment

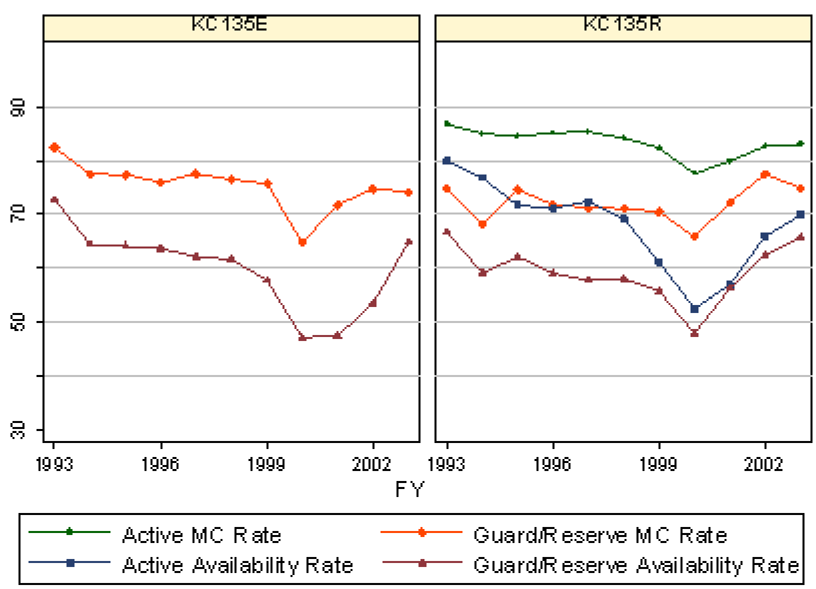
Our principal conclusion is that trends in KC–135 readiness and maintenance resource requirements are reasonably steady and that corrosion has not been a major contributor in those cases where adverse trends have been observed. In the case of the depot, backlog problems in the late 1990s that arose for various reasons have largely been overcome using improved management approaches that have resulted in much faster job completion and more efficient use of labor. The improvements are evident throughout the Programmed Depot Maintenance (PDM) process and have resulted in labor savings in most parts of the process, including corrosion repair.

In this report we will discuss each of the six specific assessment topics listed on page 1. First, we will address operational readiness and groundings to provide a summary of the overall condition of the KC–135 fleet. Next, to develop a more complete picture of the material condition, and the impact of corrosion in particular, we will identify the major process changes in corrosion control and treatment. We will then use that information to analyze trends in labor hours at the O- and D-levels. Following a brief review of MSR trends, we will conclude with a summary of our findings.

Operational readiness trends

We calculated two measures of readiness: a mission-capable (MC) rate and an availability rate. The MC rate is the percentage of time that aircraft possessed by an operating unit are either fully or partially mission-capable (FMC or PMC). Thus, the MC rate is a measure of the readiness of aircraft that are assigned to operational units. However, the MC rate provides only a partial picture of the material readiness of the KC–135 fleet, because it fails to account for aircraft at the depot. It is possible that an MC rate could hold steady, while the number of aircraft available to perform missions declines as more aircraft are in the depot. The availability rate is the percentage of time that all aircaft, including those at the depot, are MC. Thus, the availability rate will always be less than the MC rate. Our preliminary analysis of the data indicates that readiness was fairly constant from FY 1996 through FY 1998, began to decline in FY 1999 and considerably in FY 2000, and has since recovered. Figure 1 below plots these trends. The trends for the different series are similar, as are the trends for Active and Reserve/Guard aircraft.

Figure 1. KC135 Readiness trends



Groundings

We examined two measures of corrosion-related groundings: maintenance time associated with corrosion-related Time Compliance Technical Orders (TCTOs) and all corrosion-related maintenance time (except TCTOs). Our data specify the amount of time that an aircraft is under maintenance, but not the time that the aircraft is awaiting maintenance. In addition, the data do not specify the severity of the equipment problem—some problems do not seriously degrade capabilities. Thus, we cannot fully identify the amount of time that an aircraft is grounded pending maintenance. Nevertheless, the available data provide insight into trends regarding corrosion-related groundings.

Time Compliance Technical Orders

TCTOs are instructions from the KC–135 System Program Office (SPO) to inspect and correct a potentially fleet-wide material problem. The KC–135 SPO identified six corrosion-related TCTOs between FY 1996 and FY 2003.[1] We calculated the number of aircraft reporting work to complete these actions as well as the amount of clock time and number of labor hours required. Corrective maintenance to repair problems discovered during a TCTO inspection is not specifically identified in the data, but we identified maintenance actions that began soon after the TCTO was completed and were done on the same equipment. We reviewed these related actions as a possible indicator of the extent of problems revealed during TCTO inspections. The data indicate that:

- Corrosion-related TCTOs are not increasing in frequency, number of aircraft affected, or number of labor hours required. The amount of clock time required to perform the TCTO is not consistently growing.
- The number of repair actions associated with TCTOs is not increasing. The relative number of potentially related maintenance actions is not increasing over time, as measured by the number of elapsed hours and labor hours required for direct

1. One of these was issued in FY 1995, but was not rescinded until FY 1996. We included it for completeness.

TCTO performance, relative to the number of potential corrective maintenance actions.

Maintenance actions

A broader measure of corrosion-related groundings includes all maintenance actions that are identified as corrosion-related. Again, we report only the actual amount of clock time during which maintenance actions identified as corrosion-related were performed. These data indicate that:

- The amount of elapsed time spent on corrosion-related maintenance actions varies from year-to-year, and has no discernable trend. The mean annual elapsed time for KC–135Rs ranged from about 32 hours in FY 1996 and FY 2003 to almost 45 hours in 1998; for the KC–135Es, it ranged from about 44 hours in FY 2001 to almost 63 hours in FY 1998.
- The proportion of the fleet reporting maintenance actions related to corrosion has been steady: about 90 percent each year for both the KC–135E and KC–135R. In FY 1998 and FY 2003, 93 percent of KC–135R aircraft had corrosion-related maintenance, a rate that was somewhat higher than is typical.

Changes in corrosion repair processes

Depot level

In the late 1990s, the depots that overhaul KC–135s were experiencing significant problems that were causing increases in both the length of time and the number of labor hours needed to complete a PDM. Starting in FY 2001, the depot at Tinker AFB undertook a major revision of PDM processes in an effort to improve turnaround time and make more efficient use of resources. Among the steps they took were:

— Made greater efforts to do MSRs concurrently with other work

— Adopted critical path methods

— Deployed additional technical staff on the depot floor and in the field

— Moved the airframe less often and used more versatile jig-and-jack configurations

— Ceased doing major modifications concurrently with PDMs

— Introduced pre-inspections, which aided planning

— In late 2000, reduced the number of inputs to get the backlog under control.

By 2002, these changes had begun to make a difference at Tinker. They affected nearly all parts of the PDM process, including those related to corrosion repair.

However, the technology specifically associated with corrosion work at the depot has not changed appreciably since the mid 1990s. There have been some improvements in non-destructive inspection (NDI) technology, but these are thought to have had relatively little impact in the context of the other changes going on at the organic depot. By and large, once corrosion has been identified, the methods for dealing with it at the depot have not changed since 1996.

O-level

In the field units, the most significant process changes have been associated with corrosion inspection schedules, with a major corrosion-control inspection (CCI) requirement having come into force in 1998. In addition, there have been a number of improvements in the equipment used for corrosion repair and in the materials and equipment used for various corrosion prevention procedures and treatments. However, the constantly evolving nature of these improvements makes it difficult to identify the ones that have had a major effect on the resource requirements for O-level maintenance.

Trends in maintenance manhours

This section addresses NDAA tasks 2, trend analysis of labor hours, and 5, evaluation of the impact of changes in corrosion control and repair practices on labor hours.

Depot level

Using the maintenance data for FY 1998 through FY 2003 provided by the depot at Tinker AFB, we developed two statistical models designed to capture trends and other factors related to depot maintenance man-hours. One model looks at the total number of maintenance man-hours for a given PDM using information specific to a particular aircraft, such as date of induction and various control variables. The second model applies the same approach to a subset of the total number of man-hours that are associated with tasks that are specifically related to corrosion.[2] The control variables include information on year of manufacture, series (that is, KC–135E, R, or T), the previous location of the aircraft, maintenance effort expended on the aircraft at the O-level, and whether concurrent modifications were undertaken during the PDM. The models allow for time trends independent of these controls, and are further structured to allow for a discontinuity in the time trend after FY 2001, to pick up changes after that time.

In our technical review, we may refine these models. With that proviso, the total hours model indicates the following:

- Prior to 2001, the average number of PDM labor hours was trending upwards at about 10 percent per annum after controlling for the variables mentioned above. From about 2001 onward, the trend was reversed, with the decline occurring at about the same annual percentage rate as the earlier increases.
- KC–135s built before 1957 require about 14 percent more labor hours than those built later.
- KC–135Es require about 11 percent more maintenance labor hours than do KC–135Rs.

2. The data did not allow us to clearly identify the number of man-hours expended in work specifically related to corrosion, so we have instead identified a set of PDM tasks that are often necessitated by corrosion. This set of tasks is probably too inclusive: that is, the number of hours that we classify here as “corrosion related” is probably larger than it should be. For our final documentation, and after, discussions with depot engineering staff, we may refine our definition of corrosion hours.

- Aircraft sent from high-corrosion (generally coastal) locations required about 18 percent more labor hours than did other aircraft.
- O-level effort had a significant and negative effect on depot labor hours. More time spent working on the aircraft in the field results in fewer hours required at the depot, all else being equal.
- Concurrent Pacer-CRAG modifications imposed a substantial extra burden on the depot.

When we looked at corrosion labor hours only, we found similar results. The only exception is that the relationship between corrosion-related hours at the O-level and similar hours in the depot was *positive*, indicating that an aircraft that needed more corrosion-related work in the field is probably going to need more such work at the depot.

Our overall conclusion is that the changes that the depot instituted starting in 2001 have had the desired effect of improving overall efficiency and turnaround time, and that as a result, there appears to have been no significant increase in total or corrosion-related maintenance at the depot.

O-level

As we did in the D-level analysis, we modelled both total labor hours and corrosion-related labor hours at the O-level for an aircraft for a month. For each aircraft we calculated monthly totals of the number of labor hours expended both on corrosion-related maintenance and on all maintenance.[3] To identify the underlying time trend in labor hours, we combined these data with control variable data that could affect the number of labor hours.[4] We also include variables that will capture the

3. This analysis uses a subset of a dataset of over 4 million individual maintenance actions performed on KC–135 aircraft between FY1993 and FY2003. We used a subset of the data for which we have corresponding possession data so that we can attribute labor hours to O-level maintenance.
4. Other control variables not discussed above include indicators for Active or Reserve and Guard, forward deployment, the number of aircraft at a location, the time the aircraft was assigned to an operational unit, variables for the time since the last overhaul, and indicators for calendar month.

impact of the significant change in inspection practices in FY 1998. The impact of continuous improvements in materials and tools cannot be identified separately; they are instead reflected in the underlying trends in labor hours.

Our analysis of the total labor hours model indicates the following:

- The change in aircraft inspection practices had two effects. It had a one-time effect of increasing the number of labor hours by about 12 percent. It reduced the growth in the number of labor hours per month from about 0.3 percent per month to about 0.09 percent per month.
- An aircraft that spent the entire month in a high corrosion environment would require about 20 percent more labor hours than an aircraft in a low-corrosion environment.
- KC–135R aircraft require about 16 percent fewer labor hours than do KC–135E aircraft.

Our preliminary analysis of the corrosion labor hours model indicates the following:

- The change in aircraft inspection practices increased corrosion-related (inspection and correction) labor hours by about 16 percent. The underlying trend in corrosion related hours after the change was decreasing by about 0.2 percent per month, about the same as before the change. These are short-term trends, and extrapolating beyond the data sample may lead to inaccurate conclusions.
- An aircraft that spent the entire month in a high corrosion environment requires about 30 percent more labor hours as does an aircraft in a low-corrosion environment.
- The vintage of the aircraft had no statistically significant effect on the number of corrosion-related labor hours required.
- KC–135R aircraft require about 16 percent fewer labor hours than do KC–135E aircraft.

Major Structural Repairs

In general, the summary data on major structural repairs (MSRs) provided to us by the organic depot give no indication of an upward trend in these actions, with one specific exception. Among the categories of MSRs identified in the data—bulkheads, floor beams, body skins, bottle pin fittings, wing, and other—the only one that showed any clear upward trend between 1996 and 2003 was "other." Closer examination of the data revealed that the increase in this area was due primarily to increases in the number of nose wheel well skin and overwing hatch repairs. Depot engineering staff have told us that fatigue, not corrosion, creates the need for these repairs. Therefore, we see no evidence that corrosion is causing an increase in MSRs.

Summary

Our analysis of the material condition of the KC–135 fleet addresses the six taskings of the NDAA. In summary, we observe that:

1. Operational readiness, as measured by MC rates and availability rates, was steady from 1996 though 2003, with the exception of a temporary dip around 2000.
2. We analyzed labor hour trends in four ways. In summary:
   - Controlling for possible exogenous factors, we found that the total number of O-level maintenance labor hours was increasing at a significant rate before a major corrosion inspection was implemented in 1998. The inspection is correlated with both a significant jump in labor input and a slowing of the growth rate to a nominal level.
   - The number of O-level corrosion-related labor-hours was decreasing prior to the introduction of the inspection. The inspection led to a jump in the number of hours, but the downward trend was not significantly changed.
   - Controlling for exogenous factors, we found that the overall number of D-level hours was trending upward before new management practices were implemented in 2000. Since the implementation, the overall number of D-level hours has been declining.

- Trends in corrosion-related labor hours at the D-level were very similar to the trends for overall D-level hours.

3. There is not steady upward trend in the number of aircraft requiring corrosion repair or in the amount of time required to repair the corrosion.
4. The Air Force has increased the number of field-level corrosion inspections and has implemented a number of improved technologies, including better non-destructive inspections at the depot and the use of better sealants and tools in the field.
5. The estimated downward trend in the number of corrosion repair labor hours at the field level, and the jump in the number of labor hours associated with the inspections can be attributed to the changes in corrosion control and treatment practices.
6. The number of corrosion-related major structural repairs is not increasing.

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